ENVIRONMENTAL CONSULTING & MANAGEMENT
ROUX ASSOCIATES, INC.
402 HERON DRIVE
LOGAN TOWNSHIP, NEW JERSEY 08085 TEL 856-423-8800 FAX 856-241-4670

June 29, 2017

Ms. Erica Bergman
NJDEP – Bureau of Case Management
401 East State Street – Mail Code 401-05
P.O. Box 420
Trenton, New Jersey 08625-0420

Subject: **Perfluoroalkyl Compound Investigation Report**
Solvay Specialty Polymers USA, LLC
10 Leonard Lane
West Deptford, New Jersey 08096

Dear Ms. Bergman:

As the Licensed Site Remediation Professional (LSRP) retained by Solvay Specialty Polymers USA, LLC (Solvay), I have reviewed the attached Perfluoroalkyl Compound Investigation Report (Report) for the Solvay West Deptford Plant and am submitting on behalf of Solvay. Enclosed are three copies of the Report for your internal distribution.

Sincerely,
ROUX ASSOCIATES, INC.

Thomas R. Buggey, LSRP #580659
Vice President/Principal Hydrogeologist

cc: Nidal Azzam – U.S. Environmental Protection Agency Region 2 (via email)
Mitchell Gertz – Solvay Specialty Polymers USA, LLC (via email)
Christopher Roe – Fox Rothschild (via email)
Erin Palko – Integral Consulting Inc. (via email)

Enclosures

integral consulting inc.

PERFLUOROALKYL COMPOUND INVESTIGATION REPORT

Solvay Specialy Polymers USA, LLC
West Deptford Plant
10 Leonard Lane
West Deptford, NJ 08086
SRP PI No. 015010
Activity Number RPC1400022 – Solvay PFCs

Prepared for
Solvay Specialty Polymers USA, LLC
10 Leonard Lane
West Deptford, NJ 08086

Prepared by
Integral Consulting Inc.
923 Haddonfield Road
Suite 300
Cherry Hill, NJ 08002

June 30, 2017

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PERFLUOROALKYL COMPOUND INVESTIGATION REPORT

Solvay Specialty Polymers USA, LLC
West Deptford Plant
10 Leonard Lane
West Deptford, NJ 08086
SRP PI No. 015010
Activity Number RPC140002 – Solvay PFCs

Prepared for
Solvay Specialty Polymers USA, LLC
10 Leonard Lane
West Deptford, NJ 08086

Prepared by

integral consulting inc.
923 Haddonfield Road
Suite 300
Cherry Hill, NJ 08002

June 30, 2017

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ACRONYMS AND ABBREVIATIONS

AFFF	aqueous film forming foam
ALS	ALS Environmental
AOC	area of concern
bgs	below ground surface
DoD	Department of Defense
ECF	electrochemical fluorination
EDD	electronic data delivery
EDSA7	Electronic Data Submittal Applications, version 7.1.5
foc	fraction organic carbon, equivalent to TOC divided by 10^6
FSP	field sampling plan
IGW SRS	impact to groundwater soil remediation standard
Integral	Integral Consulting Inc.
Kd	partition coefficient, equivalent to the ratio of chemical concentration in soil divided by chemical concentration in water
Koc	organic carbon normalized partition coefficient, equivalent to Kd divided by foc
LC-MS/MS	liquid chromatography-mass spectrometry/mass spectrometry
LSRP	Licensed Site Remediation Professional
MDL	method detection limit
MUA	municipal utilities authority
NaPFO	sodium perfluorooctanoate
NJDEP	New Jersey Department of Environmental Protection
ORP	oxidation reduction potential
PFAA	perfluoroalkyl acid
PFAS	perfluoroalkyl substance
PFBS	perfluorobutanesulfonic acid
PFC	perfluoroalkyl compound
PFDA	perfluorodecanoic acid
PFDoDA	perfluorododecanoic acid

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PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFTrDA	perfluorotridecanoic acid
PFUnDA	perfluoroundecanoic acid
Plant	West Deptford, New Jersey, Plant
ppb	parts per billion
ppt	parts per trillion
PRM	Potomac-Raritan-Magothy aquifer
PTFE	polytetrafluorethene (Teflon ®)
QAPP	quality assurance project plan
QA/QC	quality assurance and quality control
RL	reporting limit
RPD	relative percent difference
SDG	sample delivery group
Solvay	Solvay Specialty Polymers USA, LLC
SOP	standard operating procedure
SRP	Site Remediation Program
TOC	total organic carbon
TSS	total suspended solids
TWP	temporary well point
VOC	volatile organic compound
VOC	volatile organic compound
WWTP	wastewater treatment plant

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EXECUTIVE SUMMARY

Solvay Specialty Polymers USA, LLC (Solvay) has completed field investigation work to evaluate the presence of perfluorononanoic acid (PFNA) and other long carbon-chain perfluoroalkyl substances (PFASs) in groundwater, soil, surface water, sediment, and pore water at or near the West Deptford, New Jersey, Plant (Plant) and to better understand the distribution of PFASs and their potential transport pathways. This interim report is submitted by the Licensed Site Remediation Professional (LSRP) for this investigation under the New Jersey Department of Environmental Protection (NJDEP) Site Remediation Program (SRP), Program Interest No. 015010 (SRP PI No. 015010) and Activity Number RPC140002 – Solvay PFCs.

The investigation was completed under the oversight of an LSRP following the *Work Plan Perfluoroalkyl Compounds* (Work Plan; Integral 2015b), dated September 22, 2015, comments on the Work Plan received from the NJDEP on March 7, 2016, and the *Response to NJDEP Comments* letter submitted to NJDEP on May 6, 2016. The Work Plan was approved by the NJDEP in a letter dated August 12, 2016. Over the course of implementation of the Work Plan, Solvay expanded the investigations on its own initiative in consultation with the LSRP.

The scope of the investigation included the following field sampling programs: 1) soil sampling onsite and at limited locations offsite; 2) installation of 16 new offsite groundwater monitoring wells and sampling of onsite and offsite monitoring wells; and 3) surface water, sediment, and pore water sampling within the Main Ditch and Little Mantua Creek. Based on the results of the field investigation, the development of site specific impact to groundwater soil remediation standards (IGW SRSs) for the soil to groundwater pathway was completed.

The following areas of concern (AOCs) were evaluated at the site: AOC-PFAS Soil, AOC-PFAS Groundwater, and AOC-PFAS Surface Water/Sediment. The findings of the investigation by AOC are as follows:

- **Soil.** An area of elevated PFASs in soil has been identified onsite. This area corresponds to the highest observed PFAS concentrations and vertical distribution of PFAS, and is located within and proximate to the production area (Polymer Building) and materials storage areas. PFAS levels in soil outside of the production areas at the Plant site are considered minor and are not believed to represent a significant source of PFAS to groundwater. PFNA in these areas at depths between 2 and 5 ft below ground surface (bgs) is generally less than 20 ng/g (0.02 mg/kg). These lower levels of PFASs in soils may be the result of air deposition from identified emission sources located near the Polymer Building. This is consistent with the significant decrease in PFAS in soil on the Plant site with distance downwind from the identified emissions sources.

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Soil desorption equilibrium testing of Plant site soils was conducted and yielded site-specific partition coefficients for PFNA. Applying this information and NJDEP's spreadsheet tool for calculating preliminary site-specific IGW SRS, yielded a value of 20 ng/g or 0.020 mg/kg for PFNA in soil.

PFNA concentrations in soil collected from the offsite monitoring well locations are well below 20 ng/g and range from nondetect (i.e., <1 ng/g) to 2.6 ng/g. Based on the concentration gradient (e.g., the concentration of PFNA at location MW-101, located closest to the Site, is lower than that observed at all other locations), there is no discernible direct pathway for PFNA from the site consistent with our air dispersion model.

- **Groundwater:** Groundwater flow in the Upper Potomac-Raritan-Magothy aquifer (PRM), the primary aquifer evaluated as part of the implementation of the Work Plan, is to the south-southeast. These results are consistent with water levels observed in onsite and offsite Solvay monitoring wells as part of an ongoing groundwater investigation and monitoring program for volatile organic compounds (VOCs) conducted at the Site. The remedial investigation report documenting completion of the remedial investigation was submitted to the NJDEP in May 2014 (ERM 2014). For groundwater to flow from the Plant to wells located near Woodbury Creek, it would need to flow cross gradient from the flow direction observed at the Plant, and through the monitoring well transect consisting of MW-101S/D, MW102S/D, and MW-103S/D. The data collected during this study do not support such a groundwater flow path. Rather, the water level gauging data coupled with the spatial distribution of PFAS results (including isomer chemistry) indicate that there is no hydrologic connection between groundwater at the Plant and groundwater near Woodbury Creek. PFASs in groundwater have been characterized along the flow path including delineation of the downgradient extent of PFASs as defined by monitoring wells MW-108S/MW-108D and delineation along the southwest edge of the plume as defined by monitoring wells MW105S/MW-105D and MW-106S/ MW-106D.

  Furthermore, an evaluation of branched and linear isomer composition of the groundwater samples shows that branched PFNA and perfluorooctanoic acid (PFOA) is present from source(s) not related to Solvay or any historic operations at the Plant location that preceded and are known to Solvay. To Solvay's knowledge, historic Plant operations used only linear PFNA and this is consistent with the exclusively linear PFNA found in Plant groundwater. This finding contrasts with isomer chemistry evidence of co-mingling of plumes from sources other than the Plant that are occurring in the down and cross gradient areas investigated.

  Surface Water/Sediment/Pore Water: Some fraction of the PFAS in sediment proximate to the Plant may reflect historic aerial deposition to onsite soil, subsequent leaching to shallow groundwater, and transport from groundwater to adjacent surface water. PFNA concentrations are highest at locations furthest inland (away from the river) in

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substrate comprised of larger grain sizes. Concentrations of PFASs, including PFNA, exhibited very low spatial variability in both surface water bodies.

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1 INTRODUCTION

On behalf of Solvay Specialty Polymers USA, LLC (Solvay), this report presents the results of the investigation activities completed from August 2015 through February 2017 at Solvay's facility located in West Deptford, New Jersey (Plant), downgradient (south-southeast) of the Plant, and in adjacent surface water bodies including Little Mantua Creek and the Main Ditch, as shown on Figure 1. The investigation was completed under the oversight of a Licensed Site Remediation Professional (LSRP) following the *Work Plan Perfluoroalkyl Compounds (*Work Plan; Integral 2015b), dated September 22, 2015, comments on the Work Plan received from the New Jersey Department of Environmental Protection (NJDEP) on March 7, 2016, and the *Response to NJDEP Comments* letter submitted to NJDEP on May 6, 2016. The Work Plan was approved by the NJDEP in a letter dated August 12, 2016.

The report includes results of vertical profile samples collected prior to the submittal of the Work Plan. Prior to implementation of the Work Plan, vertical profile samples for perfluoroalkyl substances (PFASs) analysis were collected in August and September 2015 and February 2016 from six temporary well points (TWPs) installed as part of sampling for a separate volatile organic compound (VOC) investigation conducted under Site Remediation Program (SRP) PI No. 015010; ECRA/ISRA Case No. E20020018 at six locations: TB-77, TB-78, TB-79, TB-80, TB-81, and MW-41D.

The objectives of the Work Plan were to evaluate the presence of perfluorononanoic acid (PFNA) and other long carbon-chain (PFASs) in groundwater, soil, surface water, sediment, and pore water at or near the Plant, and to better understand the distribution of PFASs and potential transport pathways to the environment.

The investigation included the following activities in each area of concern (AOC):

- Soil – Collection of surface and subsurface soil samples for the analysis of PFASs from the Plant and from offsite monitoring well locations, and subsequent chemical analysis using an adaptive sampling approach.
- Soil – Completion of a soil desorption equilibrium study with site-specific soils to quantify PFNA partition coefficients for use in evaluating the potential for leaching of historic PFNA deposition from soil to groundwater.
- Groundwater (Monitoring Wells) – Installation of 16 monitoring wells at 8 locations offsite (each location has a nested pair, screened at different depths).
- Groundwater (Monitoring Wells) – Collection of groundwater samples for the analysis of PFASs and general chemistry parameters from 58 monitoring wells (including all 16 monitoring wells installed as part of the implementation of the Work Plan).

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- Groundwater (Temporary Well Points) – Collection of co-located groundwater samples for the analysis of PFASs and subsurface soil samples for the analysis of total organic carbon (TOC) and grain size distribution from temporary wells installed offsite.
- Sediment/Surface Water – Collection and chemical analysis of co-located sediment, surface water, and pore water samples from the Main Ditch and Little Mantua Creek, including measurements using tide stages and collection of surface water samples during high and low tides.
- Evaluation of PFAS isomer chemistry for potential source differentiation.

The sampling was conducted based on field methods presented in the *Quality Assurance Project Plan* (QAPP) and the *Field Sampling Plan* (FSP) provided as Appendix A and Appendix B, respectively, of the Work Plan. Modifications to the QAPP or FSP were made based on field conditions at the time of sampling as discussed in Section 3 in detail.

Section 2 of this report presents the site description and the geologic and hydrogeologic settings. Section 3 includes a summary of the investigation activities completed as part of the Work Plan implementation. Section 4 discusses the data quality approach and findings, and Section 5 presents the results of the investigation. Section 6 presents a summary and discussion of results.

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2 SITE DESCRIPTION

This section summarizes the Site's physical setting (location, land use, and surface water bodies) and geology and hydrogeology.

2.1 SITE LOCATION AND LAND USE

The Site comprises 243 acres at 10 Leonard Lane in West Deptford Township (formerly Thorofare), Gloucester County, New Jersey (Figure 1). The Site is zoned for industrial uses and is currently used solely for the manufacturing of industrial chemicals, with some leased agricultural use and natural areas. No changes to zoning or uses are anticipated for the Site.

Surrounding land parcels within 200 ft of the Site are zoned for manufacturing and are used either for industrial, commercial, or leased agricultural purposes. The Site is bounded by a commercial freight rail line to the south and the Delaware River to the north. South of the rail line is a commercial/light industrial and agricultural property, with a mix of light industrial and residential properties located farther south beyond Crown Point Road. Little Mantua Creek borders the Site to the west, beyond which is a petroleum refinery. East of the Site are undeveloped properties.

2.2 SURFACE WATER

Surface water at the facility drains to either the Little Mantua Creek to the west of the Site, the Main Ditch to the east of the Site, or an unnamed tributary of Little Mantua Creek that traverses the Site and flows to the Delaware River (Figure 1). The entire active plant portion of the facility drains to a storm water collection system that discharges to an unnamed tributary of the Little Mantua Creek.

2.3 SITE GEOLOGY AND HYDROGEOLOGY

The Site is located in the Coastal Plain physiographic province. The formations of the Coastal Plain range in age from the Cretaceous to the Holocene periods and lie unconformably over Precambrian and lower Paleozoic metamorphic rocks. The sediment of the Coastal Plain form a wedge that dips and thickens to the southeast. A cross section showing the sequence of the Coastal Plain sediment from the Delaware River, extending approximately 3 miles along the predominant groundwater flow direction, is included in Appendix A.

The Coastal Plain is divided into formations characterized by alternating sequences of sand, clay, and gravels, each separated by a confining unit generally comprised of silty clay. The

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formations that outcrop within the vicinity of the Site include the Potomac Group, Raritan Formation, Magothy Formation, and the Merchantville Formation. The Solvay property is located entirely within the outcrop of the Magothy Formation. Together the Potomac Group, Raritan, and Magothy Formations (PRM) form the PRM aquifer system.

The PRM aquifer system underlies most of Gloucester, Camden, and Salem counties. Where present, the PRM is subdivided into upper, middle, and lower units with confining units separating the water-bearing zones. The first occurrence of shallow groundwater at the Site occurs in the Upper PRM. This aquifer has been further subdivided as part of the ongoing groundwater investigations into upper, intermediate, and deep zones. Monitoring wells installed by Solvay in the Upper PRM are labeled with an "S", "I", and "D" to designate their screened interval within the shallow, intermediate, and deep zones, respectively. An analysis of historical and current groundwater elevation data indicates that fluctuations in groundwater elevations in wells screened in the Upper PRM are consistent between the shallow, intermediate and deep monitoring wells, indicating that the Upper PRM above the clay layer is one hydrostratigraphic unit and that the zones are hydraulically connected.

Local and regional groundwater flow is toward the south/southeast away from the Delaware River due to the influence of pumping of the Upper PRM in Camden and Gloucester Counties. The Upper PRM in the vicinity of the Site, which is the aquifer zone under investigation, is primarily recharged from direct precipitation on the outcrop of the Magothy Formation with potential secondary recharge from the Delaware River. The outcrop extends from the Delaware River to Crown Point Road in the vicinity of the Site. The lower units (middle and lower PRM) outcrop beneath and across the Delaware River and would be expected to receive contributions from both the river and from precipitation on the outcrop.

The depth to groundwater within the Main Plant Area generally ranges from 10 to 20 ft below ground surface (bgs). Groundwater elevations in wells at the Site range from 2 ft above mean sea level to 10 ft below mean sea level with variations due to seasonal fluctuations.

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3 INVESTIGATION

The following sections summarize the soil, groundwater, and sediment/surface water/pore water sampling conducted as part of the Work Plan. In addition, Solvay utilized information obtained from TWPs and monitoring wells that were selected as part of a separate program involving a pre-design remedial investigation of VOCs in offsite groundwater associated with SRP PI No. 015010; ECRA/ISRA Case No. E20020018. Samples were collected from these locations to further characterize the spatial distribution and vertical profiles of PFASs.

3.1 SOIL SAMPLING

As presented in Section 2.3.2 of the Work Plan, soil sampling was initially proposed at 18 locations to validate air modeling results and to evaluate the soil-to-groundwater pathway. Soil sampling was conducted in the Plant area in May and June 2016 and at monitoring well locations during installation activities completed in July and August 2016. In response to NJDEP comments on the Work Plan, 24 additional soil boring locations were added at the Plant including bulk storage areas, material laydown areas, and swales.

Soil samples from onsite locations were collected in accordance with the FSP for high resolution (one sample per foot to the top of the water table) and low resolution (one sample collected from the surface [0–0.5 ft bgs], at 2–2.5 ft bgs, from mid-depth, and from 8 ft bgs or from the 6 in. interval above the water table, whichever was encountered first). Samples from the swales were collected from the 0–0.5 ft interval below the gravel/liner, where present, from mid-depth, and from the 6 in. interval above the water table. Modifications to the sampling program included a reduction in the number of samples at low resolution sample locations where the water table was shallow. Samples from the swales were collected using a combination of direct push drill rig and hand tools. Hand tools were required in several locations where sample locations could not be safely accessed by the drill rig. Soil samples collected from offsite locations were sampled in accordance with the *Response to NJDEP Comments* on the Work Plan with at least two intervals collected from each location (0–0.5 ft interval and from 2–2.5 ft bgs). Offsite soil samples were collected using hand tools as safe dig procedures precluded the collection of an undisturbed sample from the location during drilling.

Soil boring locations are shown on Figure 1. In summary, the following locations were sampled:

- Thirteen locations were sampled from lawn/grass areas not used for materials storage or production (Figure 1): SB15-01, SB15-02, SB15-06, SB15-07, SB15-09, SB15-16, SB15-17, SB15-18, SB15-19, SB-20, SB15-21, SB15-26, and SB15-34. Samples were collected using a low-resolution frequency, except for locations, SB15-01, SB15-06, and SB15-07, which were sampled on a high-resolution frequency.

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- Nine locations were sampled from areas within the main production area (areas adjacent and/or proximate to the Polymer Building; Figure 1): SB15-03, SB15-05, SB15-08, SB15-12, SB15-13, SB15-14, SB15-15, SB15-24, and SB15-25. Samples were collected using a low-resolution frequency, except for locations SB15-03 and SB15-05, which were sampled on a high-resolution frequency.
- Five locations were sampled from areas used for materials storage and bulk storage (Figure 1): SB15-04, SB15-10, SB15-11, SB15-23, and SB15-35. Samples were collected using a low-resolution frequency, except at locations SB15-04 and SB15-35, which were sampled at a high-resolution frequency.
- Five locations were sampled in the drainage swales: SB15-28, SB-29, SB15-31, SB15-32, and SB15-33 (Figure 1). Two additional swale sample locations were proposed in the Work Plan; however, water was present in the channel during the sampling event. Therefore, these locations were not considered representative of soil samples and the sample locations were eliminated from the sample program.
- Six locations were sampled as part of the monitoring well installation: MW-101, MW-102, MW-103, MW-104, MW-105, and MW-106. The locations of the monitoring wells are shown on Figure 1.

For locations on the Plant property, prior to drilling, the locations of proposed borings were marked by Integral Consulting Inc. (Integral) and Solvay, and cleared using ground penetrating radar, electromagnetic detection, and radio frequency line locating. Consistent with health and safety protocols, minor adjustments were made to the original planned locations of several borings to avoid subsurface structures. Soft dig procedures were used at off-property locations prior to drilling to evaluate for the presence of underground utilities.

Two modifications to the sample locations were applied during the sampling events. Location SB15-22 was eliminated due to the presence of utilities. In addition, a sample was not collected from location MW-107 because permission to collect a soil sample was not included in the access agreement for this property.

All samples collected from each location were submitted for laboratory analysis for PFASs. A subset of samples was also submitted to measure TOC and grain size distribution. Following completion, each boring was backfilled and the surface repaired to match the surrounding area (grass, asphalt, etc.), except for monitoring well locations. Soil boring logs are included in Appendix B.

3.2 SITE-SPECIFIC SOIL PARTITIONING COEFFICIENT

A laboratory adsorption equilibrium study was proposed in the Work Plan to determine a PFNA partition coefficient for Plant site soils. However, because all the soil samples collected

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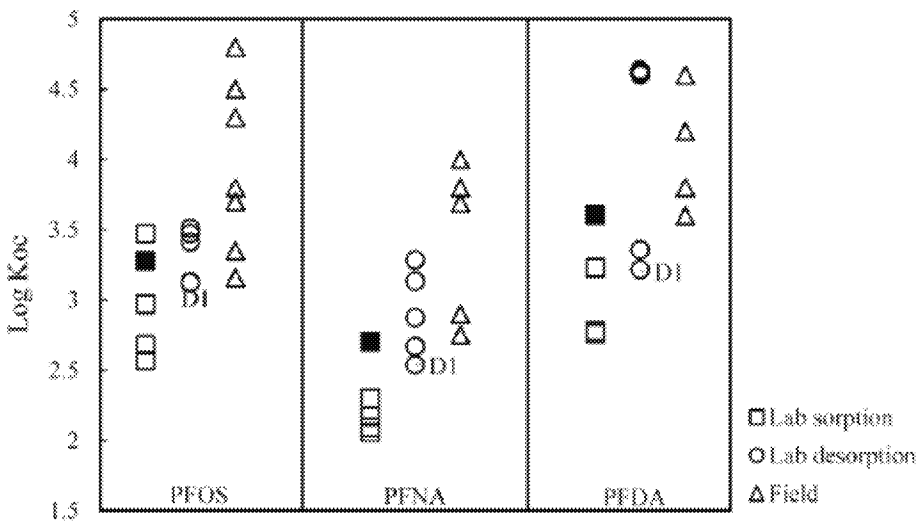
had measureable levels of PFNA, a desorption equilibrium test was substituted for the planned adsorption equilibrium test. The background and testing procedures are discussed below.

3.2.1 Background

The adsorption of PFASs to soil can be influenced by a number of site-specific factors including calcium and magnesium concentrations, organic carbon content, and pH (Higgins and Luthy 2006; Chen et al. 2016). Some PFASs, including PFNA, also exhibit sorption hysteresis[1], which can contribute to variability in partitioning over time. One study found that 65–82% of PFNA initially adsorbed to soil was observed to desorb (Chen et al. 2016). Additionally, the partition coefficient changes as more easily desorbed PFNA is flushed from the sample and the permanently sorbed fraction represents an increasingly greater proportion of the remaining PFNA. As a result, a wide range of partitioni ng coefficients and organic carbon normalized partition coefficient (Koc) values can be measured depending on whether the test is measuring initial adsorption, initial desorption, or a more advanced stage of desorption. In general, a lower leaching potential (characterized by a higher Koc value) is expected at a more advanced stage of desorption (see Graphic 1).



Graphic 1. Organic Carbon Content Normalized Distribution Coefficients Log Koc of Three Perfluoroalkyl Compounds (PFCs). Lab desorption data based on this study [open circles], D1 denotes first desorption. Lab sorption and field data derived from this study (solid squares) and literature [open squares] (see Chen et al. 2016 - Figure 5 and citations).

PFNA initially deposited to surface soils would have been subject to leaching by precipitation for many years. Under these conditions, any remaining PFNA in soil would be expected to

[1] Hysteresis occurs when a portion of the chemical that has adsorbed to the soil matrix is unavailable for desorption.

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exhibit a higher Koc. For these reasons, site-specific soil partitioning tests were performed as part of the remedial investigation.

3.2.2 Laboratory Procedure

Laboratory procedures used for the soil testing were similar to the standard operating procedure (SOP) provided with the Work Plan. However, rather than conducting an adsorption equilibrium test, a desorption test was conducted because all of the soil samples contained detectable concentrations of PFNA. Specifically, instead of adding PFNA-bearing water to clean site soils, deionized water (representing precipitation) was added to dried site soils containing a range of PFNA concentrations.

Approximately 5 g of soil were placed in a 50-mL centrifuge tube with 50 mL of water and placed on a shake table for 7 days to ensure equilibrium was reached. Following the 7-day equilibrium period, samples were centrifuged for a time period sufficient to settle particles (15 to 20 minutes) and the water from three replicates of each sample was combined and submitted to ALS Environmental (ALS) for PFASs analysis. To assess sequential leaching, an additional volume of water was added to each centrifuge tube to bring the total volume back to 50 mL and the process was repeated for a total of three desorption cycles. The masses of soil and water used in the testing are presented in Appendix C.

Results of the desorption equilibrium testing are discussed in Section 4.1.2.

3.3 MONITORING WELL INSTALLATION

A well search did not identify existing third party wells that would be accessible and appropriate for the investigation. Therefore, a network of 16 new wells was installed at 8 locations (MW-101 through MW-108) to expand the groundwater investigation (see Figure 1). At seven of the eight locations, the pair of wells includes one well screened in the shallow Upper PRM (e.g., MW-101S) and one in the deep Upper PRM (e.g., MW-101D). At one location (MW-108), the pair includes one well screened in the shallow Upper PRM and a deep well (MW-108D) screened below the confining unit. The deep well was screened below the confining unit at this location to assess groundwater beneath the Upper PRM.

The wells were installed from June 21, 2016 through January 13, 2017 by a New Jersey licensed well driller using rotosonic drilling techniques. Wells were constructed as either flush mount or with a stick-up protective casing based on the requirements of the property owners. Following installation each well was developed to remove suspended solids. Drilling wastes were containerized by the driller and staged at the Plant for characterization and disposal.

Appendix B includes the New Jersey Well Permits, well construction and lithologic logs, and Monitoring Well Certification Form B's. Well construction details are summarized in Graphic 2.

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Graphic 2. Monitoring Well Construction Log [a]

Location	NJDEP Permit No.	Screen Top (ft bgs)	Screen Bottom (ft bgs)
MW-101S	E201607160	87	97
MW-101D	E201607161	127	137
MW-102S	E201607163	107	117
MW-102D	E201607164	164	174
MW-103S	E201607166	177	187
MW-103D	E201607168	231	241
MW-104S	E201607169	177	187
MW-104D	E201607172	215	225
MW-105S	E201608541	202	212
MW-105D	E201608543	287	297
MW-106S	E201608534	140	150
MW-106D	E201608535	190	200
MW-107S	E201610349	72	82
MW-107D	E201607156	112	122
MW-108S	E201614544	227	237
MW-108D	E201614547	337	347

Notes:
bgs = below ground surface
NJDEP = New Jersep Department of Environmental Protection

[a] Well diameter and screen type: 2"diameter 0.10" slot PVC.

3.4 GROUNDWATER SAMPLING

Groundwater samples were collected from newly installed and existing monitoring wells and from TWPs installed at seven locations. The conventional sampling conducted for permanent monitoring wells and the collection of groundwater samples from TWPs for vertical profiling is described in Section 2.4.1 and 2.4.2, respectively.

3.4.1 Conventional Sampling

Fourteen of the newly installed wells (MW-101S/D – MW107S/D) and 42 existing wells were sampled from September 14, 2016 through September 22, 2016. In addition, the two wells installed in December 2016 and January 2017 were sampled on January 31, 2017 (MW108S/D). Wells were sampled in accordance with the FSP (see Appendix B of the Work Plan). All samples collected from each location were submitted for laboratory analysis for PFASs. Groundwater samples were also analyzed for conventional parameters (cations/anions), total suspended solids (TSS), pH, and alkalinity. Field sample forms are included in Appendix D.

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Prior to placement of the pump at each well location, the well was gauged to determine the depth to water. The results of the well gauging conducted during the September 2016 and January 2017 groundwater sampling events are included on Table 1. This information is used to confirm the groundwater flow direction.

The following six existing wells were originally included in the FSP of the Work Plan, but samples could not be collected during the scheduled sampling events for the reasons noted:

- MW-18S and MW-19S were dry at the time of sampling;
- MW-22X and PZ-2 were damaged, preventing access to the screen zone; and
- MW-21S and MW-21D were not sampled due to access issues.

These data gaps are not considered significant because the network of wells that were sampled in September 2016 and January 2017 provides the information needed to characterize the extent of PFASs in groundwater.

3.4.2 Temporary Well Point/Vertical Profile Sampling

Prior to implementation of the Work Plan, vertical profile samples for PFAS analysis were collected in August and September 2015 and February 2016 from TWPs installed as part of sampling for a separate VOC investigation conducted under SRP PI No. 015010; ECRA/ISRA Case No. E20020018 at six locations: TB-77, TB-78, TB-79, TB-80, TB-81, and MW-41D. The locations of the TWPs are shown on Figure 1. Groundwater samples were collected and analyzed for, at a minimum, the following PFASs: perfluorooctanoaic acic (PFOA), perfluorooctanesulfonic acid (PFOS), PFNA, perfluorodecanoic acid (PFDA), perfluoroundecanoic acid (PFUnDA), and perfluorododecanoic acid (PFDoDA[2]). The purpose of this work was to obtain information on the vertical distribution of PFASs in groundwater. Co-located soil samples were also collected for TOC and grain size analysis. At each location, at least one groundwater sample was collected from the interval just below the contact with the Merchantville Formation (glauconitic clay), as well as above the base of the Upper PRM. Two of the locations were completed as permanent wells MW-41D and TB-79/MW-44D.

Vertical profile samples were also collected from the pilot borehole at location MW-108D (Figure 1) installed in December 2016 to provide additional information about the vertical distribution of PFASs in the Upper PRM and from the lower aquifer beneath the confining unit.

Graphic 3 provides a list of the 28 groundwater samples collected from 7 locations. Collection of the groundwater samples was completed by retracting a temporary well casing to expose the

[2] Because samples were collected prior to preparation of the Work Plan, the full list of 13 PFASs were not included in the previous analysis of TWP samples. However, these are the most prevalent PFASs at the site and serve as indicators.

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drive point screen at the desired 5 ft interval within the aquifer. A "K packer" seal was used at the top of the drive point screen to seal off the groundwater in the casing. This isolated zone was then purged using a decontaminated submersible pump. The onsite geologist monitored groundwater parameters (e.g., turbidity, temperature, dissolved oxygen) until they stabilized, indicating the predominant presence of groundwater representative of the formation. After field parameters stabilized, sample containers were filled with unfiltered groundwater using polyethylene discharge tubing. All samples were collected for laboratory analysis of PFASs.

Graphic 3. Summary of Vertical Profile Sample Intervals

Count	Location	Sample Depth (ft bgs)	
		Upper	Lower
1	MW-41D	32	37
2		82	87
3		117	122
4		132	137
5	MW-108D	162	167
6		192	197
7		222	227
8		272	277
9		282	287
10		312	317
11	TB-77	92	97
12		122	127
13		180	185
14		212	217
15	TB-78	132	137
16		180	185
17		247	252
18	TB-79/MW-44	112	117
19		137	142
20		172	177
21		192	197
22		232	237
23	TB-80	142	147
24		177	282
25		220	225
26	TB-81	81	86
27		122	127
28		142	147

Notes: bgs = below ground surface

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3.5 SEDIMENT AND SURFACE WATER SAMPLING

Sediment and co-located surface water sampling was originally proposed for three locations in the Main Ditch and four locations in Little Mantua Creek. At the request of NJDEP, one additional sample location was added to both water bodies (samples SESW-08 and SESW-09, Figure 1). NJDEP also requested that surface water samples be collected at both high and low tide cycles. The following locations were sampled during the week of October 24, 2016.

- **Main Ditch** – Surface water samples were collected from four locations in the Main Ditch (SESW-04, SESW-05, SESW-06, and SESW-09) at both high and low tide. Co-located sediment samples were also collected from each of the four locations. Field parameter measurements and tidal stage were documented at the time of surface water sample collection (Appendix D).
- **Little Mantua Creek** – Surface water samples were collected from four locations in Little Mantua Creek at both high and low tide (SESW-01, SESW-03, SESW-07, and SESW-08). Co-located sediment samples were also collected from SESW-01, SESW-03, and SESW-08. Field parameter measurements and tidal stage were documented at the time of surface water sample collection (Appendix D).

Surface water samples collected from each location were submitted for laboratory analysis for PFASs. Surface water samples were also analyzed for conventional parameters (cations/anions), pH, alkalinity, TOC, and TSS. Sediment samples were submitted for laboratory analysis for PFASs, grain size distribution, and TOC.

As field sampling locations were biased to depositional areas generally located along the sides of the channel, per the FSP and in response to NJDEP comments, one surface water sample was collected from the mid-point of the water column using a peristaltic pump including dedicated/disposable sample tubing because the total water column was less than 3 ft. Sediment samples were collected at depth intervals of 0–0.5 ft, 0.5–1 ft, and from depths of greater than 1 ft.

Modifications to the sampling program included eliminating the collection of surface water and sediment samples from location SESW-02. This location was only accessible by boat and weather conditions during sampling were not suitable for safe access on the waterway. In addition, location SESW-07 was moved to the south of Crown Point Road, as similar to SESW-02, the location could only be accessed by boat and weather conditions did not permit safe access to the location.

In addition, Aqua TROLL 600 Multiparameter Sondes (Aqua TROLL 600) were proposed to be installed to measure tidal fluctuations and surface water quality parameters (pH, oxidation reduction potential [ORP], water level, etc.). Based on the conditions at the time of sampling (timing of low tide cycle for safe access, weather conditions, and flux of the tide cycle on the

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Main Ditch and Little Mantua Creek), the tide gauges were not installed to record continuous 24 hour measurements as the integrity of the equipment could not be maintained. Specifically, it was determined that the loggers would either become submerged or debris in the channels would dislodge or get caught on the cables. The data loggers were instead installed on the morning of each day of the field collection activities and retrieved each day. A summary of the field parameters and tidal levels is included in Appendix D.

3.6 PORE WATER SAMPLING

The FSP included a plan to collect pore water samples at each co-located sediment and surface water sample location (Figure 1). During the October sampling events, the samples were processed in an onsite mobile laboratory station using a portable centrifuge in accordance with the SOPs provided to NJDEP. Extracted pore water samples were submitted for laboratory analysis. The following locations were sampled as part of the pore water evaluation:

- **Main Ditch** – Pore water was extracted from sediment collected at locations SESW-04, SESW-05, SESW-06, and SESW-09.
- **Little Mantua Creek** – Pore water was extracted from sediment collected at locations SESW-01 and SESW-08.

Pore water samples collected from each location were submitted for laboratory analysis for PFASs. Pore water samples were also analyzed for sulfate, bromide, chloride, fluoride, calcium, iron, magnesium, manganese, potassium, and sodium at four locations: SESW-01, SESW-04, SESW-05, and SESW-06. Field parameters (i.e., pH and ORP) were measured at SESW-01, SESW-04, SESW-05, SESW-06, and SESW-08.

Modifications to the sampling program included the elimination of pore water samples from SESW-02 and SESW-07 due to restricted access. As noted in Section 2.5, these locations were only accessible by boat and inclement weather conditions prevented safe access to the locations. Due to the sandy substrate, the volume of water extracted at some locations was insufficient to meet the minimum amount of sample volume required for full characterization. As such, cations/anions were not submitted for analysis at locations SESW-08 and SESW-09 and field parameters were not collected at location SESW-09.

3.7 TIDE EVALUATION

Three Aqua TROLL 600 sondes were installed in monitoring wells MW-17S and MW-40S and in the Main Ditch. High frequency measurements were made over a 1-week period to assess the extent of tidal influence on water levels in monitoring wells proximate to the Main Ditch. Specifically, the sondes were programmed to record hourly measurements of dissolved oxygen,

pH, ORP, turbidity, conductivity, salinity, temperature, and pressure. The raw data files for each location are included in Appendix D.

3.8 SOURCE DIFFERENTIATION

As the products used by Solvay only contained the linear isomer[3] of PFNA, isomer chemistry is an important line of evidence for source determination and offsite characterization. Specifically, the presence of branched PFNA isomers detected in this investigation in environmental samples indicates contributions from original source materials that were not used by Solvay.

The synthesis of most perfluoroalkyl acids (PFAAs) has occurred through one of two methods: electrochemical fluorination (ECF) or telomerization. The two methods yield final products with distinctly different isomer profiles (e.g., Benskin et al. 2009; Buck et al. 2011; and Lindstrom et al. 2011):

- **ECF** produces an impure mixture of branched isomers and chain-length homologs (Benskin et al. 2009). A literature review indicates that ECF produces linear and branched isomers with mass contributions of approximately 70% to 80% linear and 20% to 30% branched (Benskin et al. 2009; Buck et al. 2011; Lindstrom et al. 2011).
- **Telomerization** produces linear isomers when the starting material (telogens and taxogens) is linear (referred to as linear-telomerization), and branched isomers when the starting material is branched (branched-telomerization).

Depending on the industrial process used (i.e., raw materials and the formulation process), there may be several different branched formations for PFNA and other PFAAs. Each process can favor a particular molecular arrangement. Once formed, the isomers themselves are stable so that a linear isomer does not degrade into a branched isomer, and vice versa.

Two fluorinated surfactant products have been used at the Plant:

- **Surflon** was manufactured by Asahi Glass Co. using a linear-telomerization process involving fluorotelomer olefins, which produced odd numbered carbon-chains like PFNA (C9).
- **Sodium perfluorooctanoate (NaPFO)** was manufactured by 3M using the ECF process until about 2002 when 3M voluntarily discontinued production of NaPFO and other long chain PFASs.[4]

[3] An isomer is a molecule with the same molecular formula as another molecule, but with a different chemical structure. Isomer composition may provide an indication of source origin when chemicals enter the environment.
[4] Long-chain PFASs are perfluoroalkyl carboxylic acids with 7 or more fully fluorinated carbons or perfluoroalkane sulfonates with 6 or more fully fluorinated carbons (OECD 2015).

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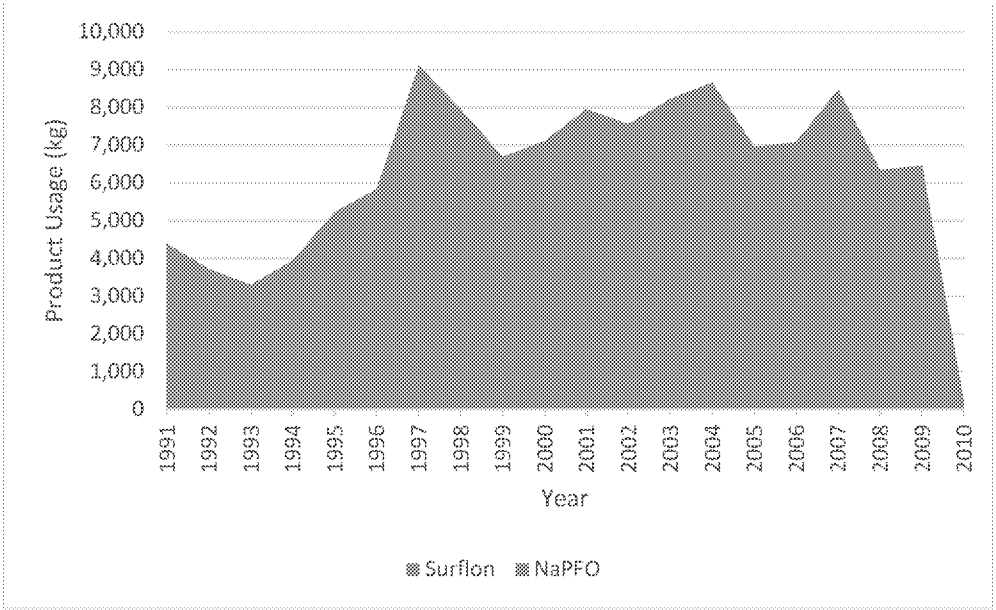
From 1991 to 2010, approximately 136 t[5] of surfactant product was used at the Plant, 92% of which was Surflon, and the remaining 8% was NaPFO. Graphic 4 shows the time line and relative usage volumes of both products.



Graphic 4. Perfluorinated Surfactant Product Usage at the Plant (1991–2010).

From the start of operations until the mid-1990s, Surflon was supplied to Solvay in solid (salt) form. From the mid-1990s until its use was discontinued, Surflon was supplied in liquid form. Legacy samples of Surflon in both forms were prepared as aqueous solutions and were submitted to Vista Analytical Laboratory for analyses. The results of the isomer analysis are summarized in Table 2. Analytical testing confirms that Surflon was manufactured by linear-telomerization because only linear isomers can be detected. These results are also consistent with prior studies of Surflon (Appendix E) that indicate a composition that is based predominantly (>98%) on odd-carbon homologs that are exclusively linear (Prevedouros et al. 2006; Buck et al. 2011). Thus, both the analysis by Vista laboratories and the independent analyses confirm that Surflon does not contain branched isomers of PFNA or other PFAAs.

Because 3M discontinued production of long-chain PFAAs by 2002, legacy samples of NaPFO could not be obtained. However, it is well documented that 3M's ECF process produced 6-, 8-, and (to a lesser extent) 10-carbon perfluoroalkane sulfonyl derivatives and associated products (Buck et al. 2011). In fact, PFOA produced by 3M had a very consistent isomer composition of 78 ± 1.2% linear and 22 ± 1.2% branched, based on 18 production lots spanning 20 years (Jin et al. 2015). 3M's ECF process did not produce PFNA. Therefore, NaPFO would not have contained PFNA.

[5] 1,000 kg is equivalent to 1 MT.

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4 DATA QUALITY ASSESSMENT

The goal of the data quality assessment was to determine the quality of each data point and to identify data points that do not meet one or more project criteria. Nonconforming data were qualified as estimated or rejected as unusable during data validation if criteria for data quality were not met. Data qualified as estimated were used for all intended purposes and were appropriately qualified in the final project database. These data may be less precise or less accurate than unqualified data; however, they are still usable. The results of quality assurance and quality control (QA/QC) sampling are shown on Table F-1 in Appendix F.

Prior to submittal for independent validation, data collected as part of the investigation were reviewed by Integral. Data generated as part of the Work Plan implementation were submitted to Laboratory Data Consultants, Inc. (Carlsbad, CA), an independent third-party validator. The first data packages generated for each matrix were fully validated, equivalent to a Stage 4 validation described in *Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use* (USEPA 2009). Validation for the remaining data was based on review of the summary forms for sample and QC data, equivalent to a Stage 2B validation. Additional validation was conducted so that 10% of the samples were validated at Stage 4 to fully assess the quality of the data. The accuracy and completeness of each data set was verified at the laboratory when the electronic data deliverables (EDDs) were prepared and again as part of data validation. Ten percent of entries to the database from the laboratory EDDs were checked against the hard-copy data packages.

The analytical data and data validation reports are included on a CD in this submission in Appendix F. In addition, the EDDs, which have been verified by Solvay to be complete and free of errors with NJDEP's online tool, Electronic Data Submittal Applications (EDSA7) version 7.1.5, are also included in Appendix F.

The results of the evaluation of PFAS data for completeness, representativeness, and comparability are summarized below:

- **Completeness.** All acceptable results (usable data) are unqualified data and U or J-qualified data. The completeness for each media for PFASs is summarized below (the goal for completeness was 90%):

Media	Completeness [a]
Soil	92%
Sediment	90%
Surface Water	64%
Pore water	97%
Groundwater	97%

[a] Completeness = (Acceptable Results/Total Results) x 100%.

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Surface water was the only media that did not meet the 90% goal. Surface water data were rejected for perfluorohexanesulfonic acid (PFHxS), PFDA, PFUnDA, and perfluorotridecanoic acid (PFTrDA) due to laboratory blank contamination (if associated sample results are less than or equal to three times the laboratory blank concentration, the sample results were qualified as BR at the reported concentration). No PFNA results were rejected.

- **Representativeness.** Low levels of PFASs were detected in some field equipment and ambient blanks and laboratory method blanks, resulting in a "UBR" data qualifier for some samples. These samples were qualified as nondetect because the estimated concentration was less than three times the concentration detected in the associated lab or field blank. A review of field sampling procedures was conducted and adjustments to the frequency of field and ambient blanks were made for each sampling event to evaluate variability in location (proximity to facility, etc.). Deviations from the original FSP are documented in Section 2 of this report. In addition, detergent, decontamination water, and field equipment were reviewed to ensure that no products potentially containing PFAS were inadvertently used.

  For the majority of samples, standard data qualifiers were applied because laboratories followed SOPs for sample holding times and chemical analysis. However, non-conformances for the following samples were identified during data validation, requiring the assignment of a "UJ" qualifier (i.e., quantitation limit/detection limit is estimated):

  - Soil – one result for PFNA at location SL0003-7.
  - Groundwater – results for PFDA, PFUnDA, PFDoDA, and PFTrDA for samples collected from GW0025, GW0026, GW0027, GW0028, GW0029, and/or GW0030.
  - Surface water – results for perfluorobutanesulfonic acid (PFBS) at all locations, and results for PFHxS at a subset of locations.

  In addition, the following soil samples were reanalyzed due to contamination in the laboratory:

  - PFOA for samples in sample delivery groups (SDGs) K1604961, K1604962, K1604963, K1604964, K1605036, and K1605049.
  - Perfluorohexanoic acid (PFHxA) for samples in SDG K1609518.

- **Comparability**. Sample collection and handling procedures adhered to the procedures specified in the QAPP and the Work Plan. Laboratory procedures generally followed standard analytical protocols, used standard units and standardized report formats, followed the calculations as referenced in approved analytical methods, and used a standard statistical approach for QC measurements. Any deviations to the QAPP or Work Plan are included in the data validation reports prepared for each SDG.

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All "U" or "J" qualified data are usable. For field blanks, standard practice is to "U" flag data below a threshold (usually 5X the blank level or just greater than the reporting limit). Data were only rejected "BR qualified" when sample concentrations were less than three times the concentration in the associated field blank. The "BR" flagged results may be biased high or they may be false positives due to the field blank contamination, however, the actual sample concentration is not higher than the "BR" flagged concentration. For this reason the "BR" qualified results are treated as nondetects and are usable to demonstrate that sample concentrations are not above the BR flagged value.

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5 RESULTS

The results of the analysis of samples collected from soil, groundwater, sediment, surface water, and pore water are presented below. Groundwater elevation data are discussed in Section 5.2.1.

5.1 SOIL RESULTS

Concentrations of PFASs in soil are presented in Tables 3 and 4 and depicted in Figures 2 through 9. Grain size distribution and TOC are presented in Appendix G. Figure 2 shows a distribution of concentrations in the soil column as a series of bar charts. Figures 3 through 6 show the results for samples collected at the surface, from just below the surface (1–1.5 ft bgs), from 2 ft bgs, and from samples greater than 5 ft bgs. Figure 7 shows the results of soil samples collected in 2014 between the Plant and the Delaware River. In addition, the results of the high resolution soil samples are included on Figure 8. The results of soil samples collected from the monitoring well locations are shown on Figure 9. Observations based on these results are discussed below.

5.1.1 Soil Sample Results

The results of the PFAS soil sampling indicate the following:

- The maximum concentration[6] of PFNA in onsite soil is 2,400 ng/g at SB15-13 (located in the main production area). Concentrations are lower by at least an order of magnitude in the areas away from and outside of the main production area (Figures 3 through 8).
- Results for high resolution vertical samples collected onsite are shown on the bar charts in Figure 2 and depicted on Figure 8. The highest concentrations of PFNA in subsurface soil tend to be between 2 and 5 ft bgs. Soil samples with highest PFAS concentrations in this soil horizon were collected from onsite locations in and around the main Polymer production area.
- PFUnDA (C11) appears to be less mobile in soil than PFNA (C9) based on the results of the vertical profiles. Concentrations of PFUnDA are present at higher concentrations at the surface than at the subsurface. This is also confirmed by the overall absence of PFUnDA in groundwater.
- PFAS concentrations (including PFNA) in soil at the offsite monitoring well locations range from non-detect to 2.6 ng/g (Figure 9).
- Lower levels of PFASs in soils outside the Plant area may be the result of air deposition from identified emission sources located near the Polymer Building. This is consistent

[6] Units of nanograms of chemical per gram soil (ng/g) are equivalent to μg/kg or parts per billion (ppb).

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with the significant decrease in PFASs in soil on the Plant site with distance downwind from the identified emissions sources.

- The subsurface lithology is relatively homogeneous across the Plant and consists of predominately medium sand with little organic material.

TOC and grain size distribution were also measured at approximately 20 locations and multiple depth intervals. Specifically, soil properties were measured for samples collected from seven onsite locations in 2014, seven onsite locations in 2016, and four offsite monitoring well locations in 2016 (MW-101D, MW-102S, MW-103S, and MW-105D). As expected, TOC concentrations are generally highest in surface soil within the first 1 ft bgs. At six locations, TOC concentrations in surface soil exceeded 15,000 mg/kg with a maximum of 88,000 mg/kg at SSI-S6. Soil TOC below 2 ft bgs is less than 2,000 mg/kg at most locations, with a minimum of 193 mg/kg at SB15-05 for a sample collected at a depth of 3–3.5 ft bgs. Within the top 10 ft bgs, soil consists mostly of sand, ranging from very coarse to very fine sand. Two samples collected below 10 ft at locations MW-101D and SB15-04 have less sand and more clay.

5.1.2 Site-Specific Soil to Groundwater Soil Remediation Standard Evaluation

Soil desorption equilibrium tests were run to develop site-specific partition coefficients (i.e., partition coefficient [Kd] and Koc)[7] for PFNA. Soils from onsite locations were collected and shipped to Integral's soil testing facility in Colorado and chemical analysis was performed by ALS (see Section 2.2). Soil PFNA concentrations were calculated as an average of two analyses and the TOC concentrations were calculated as an average of three analyses. Soil PFNA and TOC concentrations are presented in Appendix C.

The concentrations of PFNA in leachate, and measurements of the volumes of water added and removed at each stage of the experiment are used in mass balance calculations of the concentration remaining in soil at the end of each equilibrium cycle. The resulting soil and aqueous concentrations are then used to calculate Kd and Koc using the soil TOC.

Measured Koc values consistently increased with each successive round of the experiment, suggesting that PFNA becomes less mobile in soil over time. Koc increased by roughly a factor of 3 between rounds 1 and 2, and another factor of 2 between rounds 2 and 3. Use of the arithmetic mean Koc value across the three rounds essentially weights each round equally, although it may be argued that the round 3 results best mimic the current conditions of historic PFNA deposition in soils at the Plant, which have had years to equilibrate. Therefore, use of the arithmetic mean in this report may be viewed as conservative in the sense that it will yield a

[7] Kd is the ratio of chemical concentration in soil divided by chemical concentration in water, expressed as (μg chemical/kg soil) / (μg chemical/L water). Koc is the ratio of Kd divided by fraction organic carbon (foc), equal to TOC (mg/kg) divided by 1 million (i.e., 10^6 mg/kg). Log base 10 of Koc is given in this report to express quantities on a scale that has lower values.

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lower Koc than the round 3 result, thereby contributing to (modeled) predictions of a higher flux of PFNA from soil to groundwater than may actually be occurring at site soils.

Samples are grouped into two depth categories: surface soils (0–1 ft bgs) and Upper PRM sands (5–8 ft bgs). Samples with TOC less than the method detection limit (e.g., <250 mg/kg) are not used in the calculations of Kd and Koc. In the surface soil samples, TOC ranges from approximately 2,000 to 7,000 mg/kg, which is sufficient to calculate partition coefficients. By contrast, with the exception of one sample, TOC in the Upper PRM sandy aquifer material is too low to compute reliable partition coefficients.

For the two samples with the highest PFNA concentrations the laboratory followed the SOP and applied dilutions in order to bring concentrations into the calibration range of the instrument.[8] The resulting loss in analytical precision led to the exclusion of SL00024-1 (all 3 rounds) and SL0005-8 (rounds 2 and 3) from the summary of results given by Graphic 5.

Graphic 5. Site-specific Soil PFNA Partition Coefficients (log Koc [a]) by Sample

Sample [b]	TOC (mg/kg)	Round 1	Round 2	Round 3	Mean [c]
L00034-0-PT	4,307	3.6	4.3	4.3	4.1
SL00028-0.5-PT	5,953	3.6	4.3	4.6	4.2
SL0009-0-PT	6,633	4.1	4.3	4.7	4.4
SL0005-8-PT	175	3.9	-	-	3.9
Mean[3]	4,267	3.8	4.3	4.5	4.2

Notes:

Koc = organic carbon normalized partition coefficient
PFNA = perfluorononanoic acid
TOC = total organic carbon

[a] Units of log Koc are log of (µg PFNA/kg soil) / (µg PFNA/L water), or log of L/kg.

[b] Due to low TOC (e.g., <250 mg/kg), sample SL00024 is excluded and rounds 2 and 3 for SL0005-8 are excluded.

[c] Mean = arithmetic mean.

Using the NJDEP IGW SRS soil-to-groundwater partition equation spreadsheet with site-specific parameters, including a log Koc of 4.2 and an foc of 0.0043, yields a site-specific IGW SRS for PFNA of 20 µg/kg. This number reflects site-specific conditions for soils with TOC ranging from 2,000 to 7,000 mg/kg.

[8] For SL0005-8 the soil analysis was diluted 20-fold, the round 1 leachate 250-fold, round 2 leachate 50-fold, and the round 3 leachate 10-fold. For SL00024-1 the round 1 leachate was diluted 50-fold.

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5.2 GROUNDWATER RESULTS

The results of the isomer analyses are summarized in Table 5. PFAS concentrations in groundwater are presented in Tables 6 and 7. Groundwater flow direction for monitoring wells in the Upper PRM is shown in Figures 10a, 10b, 10c, and 10d and PFAS results are included in Figures 11a and 11b. The results of the analyses for conventional parameters (cations/anions), TSS, pH, and alkalinity are summarized in Table 8.

5.2.1 Isomer Analysis

As part of the remedial investigation, Solvay evaluated laboratory reports to estimate the isomer composition of PFAAs, including PFNA, detected in groundwater monitoring wells located both onsite and offsite. In addition, samples of the products containing PFAAs known to have been historically used at the facility were researched and analyzed for their isomer composition. This report presents the findings from evaluations of PFAS isomer chemistry.

Groundwater samples were evaluated for the presence of branched and linear isomers for PFNA and PFOA. The chromatograms from the 2016 water samples were examined and evidence of branched PFOA and PFNA was observed in multiple samples. This observation was made by a review of the liquid chromatography-tandem mass spectrometry (LC-MS/MS) analyses provided as part of the laboratory data package. As shown below (see Graphic 6), the branched PFAS isomers elute just before the linear isomer. Through examination of the ion profiles for each sample, the relative heights of the linear and branched isomers can be determined and then used to estimate the percentage of the total concentration contributed by each isomer.

Not only did we detect branched PFNA, which is indicative of other sources, we also detected branched PFOA, which also supports the conclusion that there are additional sources of PFAS in groundwater. The estimated percent of the total PFOA and PFNA concentrations that is from branched isomers as determined from a review of the laboratory chromatograms is presented in Table 5. The results of the analysis show the following:

- Only linear PFNA has been detected in the Upper PRM unit above the confining layer at the Plant site.
- Branched PFNA is present in groundwater at monitoring wells screened in the Upper PRM at the following locations (see Figure 1), with the percent branched given for each:
  - Southwest of the Plant (shallow and deep Upper PRM well pairs): MW-105S (23%)/MW-105D (20%), MW106S (62%)/MW-106D (35%-53%), and MW-107S (17%)/MW107D (17%); and
  - Southeast of the Plant: MW-101D (6%) and MW-103D (8%).

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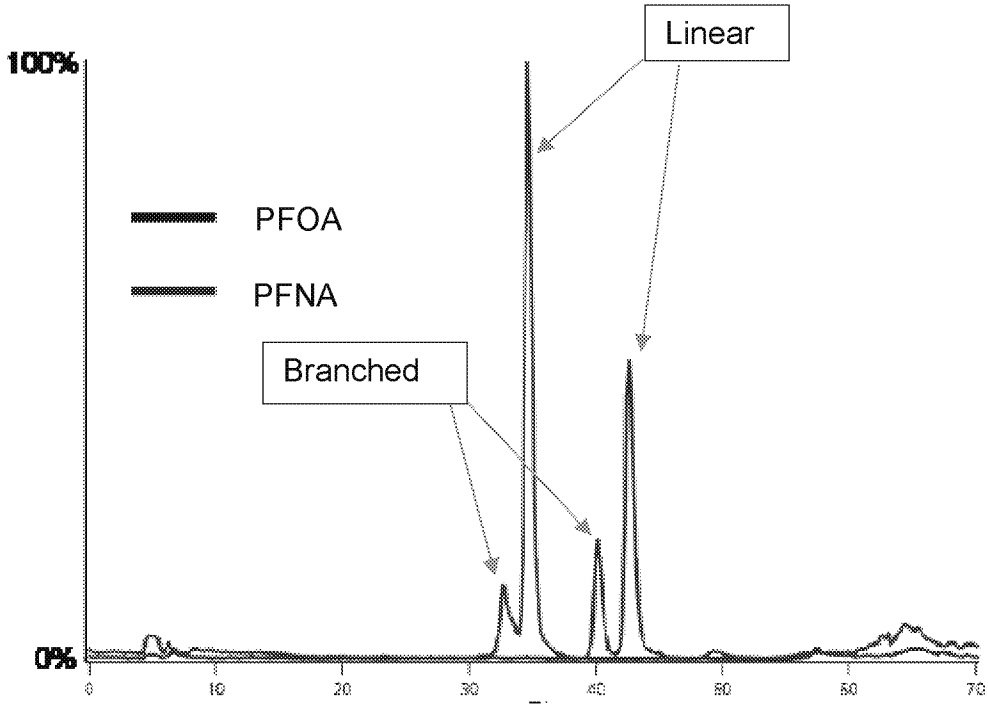

Graphic 6. Example LC-MS/MS PFOA and PFNA (Benskin et al. 2007).

- At depth, below the confining unit, branched PFNA is present at the percentages provided for each: MW-5X (29%), MW-10X (6%), and MW19X (10%).
- Branched PFOA is present in all but two locations (MW-104S/MW-104D and MW-108D), with the following notable findings:
  - The percent contribution of branched PFOA to total PFOA ranges from 6% to 52%, with an average (and median) of 20%.
  - Branched isomers comprise more than a third of the mass of PFOA at the same locations where branched PFNA is present: MW-105S (43%), MW-106S (52%)/ MW-106D (34%), MW-107D (34%), and MW-10X (39%).
  - Branched isomer compositions of PFNA and PFOA are moderately correlated ($R^2 = 0.4$) for 14 samples with branched PFOA > 25%.

The proportion of branched isomers tends to be highest among samples with concentrations of PFNA and PFOA in the range of 10 ng/L or less. This suggests there is consistency in the contribution of branched PFNA from sources not related to Solvay at such locations. Using the average concentration in groundwater screened at different intervals at the same location, Graphic 7 summarizes the average proportion of branched isomer across wells categorized by concentration ranges. For the 13 samples with branched PFNA, the percent branched shifts from approximately 40% branched (and 60% linear) among concentrations less than 10 ng/L, to

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10% branched for concentrations greater than 10 ng/L. For the 56 samples with branched PFOA, the percent branched shifts from approximately 30% branched among concentrations less than 10 ng/L, to 20% branched for concentrations greater than 10 ng/L.

Graphic 7. Average Percent Branched Isomers of PFOA and PFNA for Groundwater Samples Grouped by Concentration Range

Concentration	% Branched PFOA		% Branched PFNA	
(ng/L)	n	Mean	n	Mean
<10	8	34%	5	40%
10 to <100	14	18%	5	11%
100 to 1,000	26	17%	3	14%
>1,000	8	22%	0	N/A

Notes:
N = number of samples
NA = not applicable
PFNA = perfluorononanoic acid
PFOA = perfluorooctanoic acid

Existing data (from testing by Solvay and others as to Surflon and from testing by others as to NaPFO) show that neither Surflon nor NaPFO contain branched PFNA. Notably, branched PFNA is present in wells located cross gradient from the Plant and screened below the Upper PRM confining unit at the Plant. Branched PFNA is not present in any of the onsite wells in the Upper PRM nor in wells screened in the same unit located directly downgradient from the Plant.

Groundwater in the upper PRM cross gradient and southwest from the Plant is sourced from the upper PRM outcrop area located beneath a number of chemical and petrochemical facilities with known associations to PFAA chemicals. Groundwater in the upper PRM cross gradient and southeast from the Plant is known to be sourced from the upper PRM outcrop east of the Plant and beneath the Delaware River (USGS 1998, 2011).

There are numerous potential sources of linear and branched PFNA in New Jersey. In a recent report co-authored by NJDEP and Brick Township Municipal Utilities Authority (MUA) in 2015, PFNA detected in seven groundwater samples collected in 2013–14 was linked to a facility that manufactured polytetrafluoroethene (PTFE) and fluoroelastomer products. In November 2016, the Department of Defense (DoD) reported the presence of PFNA and other PFASs in groundwater, stemming from historic aqueous film forming foam (AFFF) use at Joint Base McGuire-Dix-Lakehurst, one of six major DoD facilities in New Jersey. A high density of fluorochemical facilities (DuPont, Arkema, ICI, Air Products and Chemicals), and petrochemical facilities (Paulsboro refinery, former BP refinery, Axeon, Sunoco refinery, Exxon R&D) are located along the Delaware River corridor. Some of these companies hold fluorochemical product patents and may have conducted fire prevention training events, in some cases with

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documented responses to fires and spills where AFFF was applied in large quantities. Landfills and wastewater treatment plants (WWTPs) are also well documented potential sources of PFNA and other PFAAs (Benskin et al. 2010; Järnberg et al. 2016).

The source of branched PFNA in groundwater in Gloucester County remains unknown. There are a number of patents involving branched telogens, but production volumes using these methods were not reported – possibly because telomerization has been performed in countries that do not require this level of documentation. Branched isomers have been detected in biologic and environmental samples in the limited number of studies where branched isomers have been analyzed (Benskin et al. 2009; De Silva and Mabury 2006; De Silva et al. 2009). A recent study on isomer profiles of PFAAs in water and soil surrounding a Chinese fluorochemical manufacturing park found WWTP influent and activated sludge enriched in branched PFNA at 20% and 40%, respectively (Jin et al. 2015). These findings suggest that PFAAs are being manufactured with branched isomers, intentionally or not, on a large scale.

Together, the distribution of branched and linear isomers of PFNA, and groundwater flow direction discussed in this report provide evidence of other sources of PFASs in groundwater adjacent to, downgradient, and cross gradient from the Plant. Specifically, since the products used by Solvay at the Plant did not contain branched isomers of PFNA, and yet branched PFNA is detected in offsite locations, it is clear that there are one or more additional sources of PFNA contributing to the groundwater system.

5.2.2 Groundwater Results

The results of the groundwater gauging and analytical sampling are summarized in the sections below.

5.2.2.1 Groundwater Gauging Results

Groundwater levels were measured in 136 wells during a 1-day period in September 2016 and from a subset of 14 monitoring wells in January 2017 (Table 1). Collectively, these water levels provide a synoptic data set for evaluating groundwater flow rates and directions. Contoured water levels from wells screened in the shallow and deep Upper PRM are provided in Figures 10a, 10b, 10c, and 10d, respectively and summarized below.

- Groundwater flow is to the south-southeast, consistent with findings presented in the March 2015 Summary Report: *Findings of PFC Investigation Conducted by Solvay Specialty Polymers USA, LLC, West Deptford, New Jersey (Appendix A, Results of the Temporary Well Point Investigation)* (Integral 2015a).

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- A slight downward gradient exists in the eastern and southern areas (i.e., MW-101S/D, MW-102S/D, MW-103S/D, MW-104S/D, and MW-105S/D). A slight upward gradient exists to the southwest near wells MW-106S/D and MW-107S/D.

- Groundwater levels varied by less than ⅓ ft among the offsite monitoring well pairs that were measured during the September 2016 sampling event in the shallow and deep Upper PRM.

- The direction of groundwater flow is similar for both shallow and deep Upper PRM wells. Water levels are between 4 and 10 ft higher in January 2017 than September 2016. The higher water levels that occurred in January are probably related to lower demands from regional pumping centers during the winter, which also likely led to a horizontal hydraulic gradient that is less steep than September 2016.

- In contrast to the horizontal hydraulic gradient, the higher levels in January 2017 contributed to a greater vertical gradient between the shallow and deep Upper PRM. The steepest downward gradient occurs between MW-102S/D and MW-104S/D, where presumably recharge from the surface is replenishing aquifer storage while less pumping is occurring. Elsewhere, water levels are essentially the same (i.e., ± ⅓ ft) between well pairs in the shallow and deep Upper PRM.

5.2.2.2 Analytical Results

- As shown in both the vertical profile sampling and in the initial groundwater characterization event, the leading downgradient edge of groundwater impacted by PFNA in the Upper PRM is currently defined by the vertical profile sampling of the pilot borehole installed at MW-108D and the results from permanent monitoring well MW-108S. In addition, the southwest edge is defined by monitoring wells MW105S/ MW-105D and MW-106S/MW-106D.
- The vertical profile sampling confirms that the distribution of PFASs in the Upper PRM are consistent and while some minor variations are present, unlike the Site VOC plume where the highest concentrations are in the lower portion of the aquifer, PFAS concentrations exhibit a more homogeneous vertical distribution in the Upper PRM.
- Consistent with prior sampling events, the highest concentrations of PFASs in groundwater are located at the Plant, with the highest concentrations observed at well MW-19D (screened in the Upper PRM). The presence of branched PFASs, including PFNA, in the groundwater below the confining layer at the Plant site (i.e., the "MW-#X" wells), as well as at locations offsite, demonstrates the existence of alternative sources.
- Based on historic and current groundwater gauging data from all upper PRM monitoring wells installed as part of the remedial investigation, groundwater from the site does not flow to the east-northeast. An alternative source or sources is

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demonstrated by the confirmed direction of groundwater flow, the relative magnitude of the concentrations of PFASs, including the concentration gradient of PFNA levels, and the presence of branched isomers.

- PFOS has also been detected in the Upper PRM; however, the highest concentrations of PFOS are located in one onsite well MW-40I (located along the eastern property boundary) and offsite monitoring wells MW-33S, MW-39S, and MW43I.

5.3 SURFACE WATER RESULTS

The results of the surface water sampling are included on Table 9 and depicted in Figure 12. The results of the analyses for conventional parameters (e.g., cations/anions), are included in Table 10.

5.3.1 Surface Water Results

The results of the surface water sampling are summarized below.

- PFASs were detected in all surface water samples collected in the Main Ditch and in Little Mantua Creek. The highest PFNA concentrations, ranging from 20 to 27 ng/L, were observed in samples collected from upstream locations of the Main Ditch (i.e., SESW-04, SESW-05, and SESW-06).
- In the Main Ditch, PFNA concentrations in surface water were consistently higher during low tide compared with high tide by as much as a factor of 3 (n = 4, relative percent difference [RPD] = 60%[9]). In Little Mantua Creek, PFNA concentrations did not exhibit a consistent pattern. Concentrations were lower during low tide at two locations (by a factor 1.5 to 6), and higher at a third location by a factor of 2 (n = 3, RPD = 80%). Similarly, variability in conventional patterns was not strongly correlated with tide cycle in either water body (RPDs generally in the range 10% to 30%).
- Concentrations of PFASs, including PFNA, exhibited very low spatial variability in both surface water bodies. In the Main Ditch, the maximum PFNA concentration at each of three stations furthest from the river (i.e., downstream) varied by 1 ng/L. At the confluence with the river (SESW-09), PFAS concentrations were lower by as much as a factor of 3. In Little Mantua Creek, PFNA was comparable to the Main Ditch during high tide (e.g., 20 ng/L at the furthest upstream location – SESW-08) and lower by a factor of 2 to 6 during low tide. Concentrations were consistently in the range of 5 to 10 ng/L in the three downstream locations of the Creek during both low and high tides.
- While TSS concentrations exceeded the FW-2/NT SE2 criteria in some samples, the elevated concentrations are unrelated to Solvay and attributed to the overall stream

[9] RPD = (range/mean) x 100%.

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classification (saline water estuary) and the conditions at the time of sampling that included high winds influencing the tide and precipitation. Chloride and sodium concentrations are consistent with the classification of the Main Ditch and Little Mantua Creek as saline water estuaries.

- Isomer chemistry composition was evaluated in a similar manner as the isomer evaluation of groundwater samples discussed previously (Section 5.2.1). Branched PFNA was detected in the Main Ditch at the location at the confluence of the Delaware River (SESW-09, 3%), as well as Little Mantua Creek at both the confluence with the Delaware River (SESW-08, 6%) and at the location furthest south (SESW-07, 6%). Branched PFOA was detected at all location ranging from 6% to 12% of the total mass for each sample.

A correlation analysis was performed to examine the relationships between PFASs and conventional surface water quality parameters. Results for 16 samples (combining low and high tide samples) show that variability in PFAS concentrations is not strongly correlated with water quality parameters in either water body. PFNA exhibits a moderate positive correlation (Spearman rho between 0.5 and 0.8) with turbidity, TOC, manganese, and iron, and a moderate negative correlation with chloride, ORP, pH, and dissolved oxygen. Correlation matrix plots and additional details regarding the correlation analysis methods and findings are presented in Appendix H.

5.3.2 Outfall Mixing Evaluation

Section 2.6 of the Work Plan describes a task to conduct an outfall mixing evaluation. The purpose of this activity is to evaluate the nearfield mixing and dilution of Solvay effluent discharge to the Delaware River and to provide information to assess the potential surface water-groundwater interactions. Prior to submittal of the mixing zone work plan to the NJDEP, further assessment is needed to evaluate the potential groundwater flow path from shallow groundwater beneath the site to the adjacent surface water bodies to determine the source of PFASs detected in surface water during high and low tides in the creeks located to the west and east of the Plant.

5.4 SEDIMENT SAMPLE RESULTS

The results of the sediment sampling for PFASs are shown in Table 11. Tabular summaries of TOC and grain size distribution are included in Appendix G. The results of PFAS sampling are depicted in Figure 13 and summarized below.

- PFASs, including PFOA, PFOS, PFNA, and PFUnDA, were detected in sediment in Little Mantua Creek and in the Main Ditch. The concentrations do not exhibit a consistent pattern with respect to vertical or horizontal distribution between sample locations.

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- The highest concentrations of PFASs, in particular PFNA, were found in samples SESW-06 (18–24 in. depth interval) collected in the Main Ditch and SESW-01 (18–24 in. depth interval) collected from Little Mantua Creek (see Figure 11). The lowest concentrations of PFASs were found in samples SESW-08, collected at the confluence of the river and Little Mantua Creek, and SESW-09, collected at the confluence of the river and Main Ditch.
- The maximum PFNA concentration measured was 7.9 ng/g in subsurface sediment at SESW-01, which is lower than concentrations measured in sediment samples collected in 2014 from the Delaware River near the Plant. The range of concentrations for all other PFNA detections is 0.29 to 6.7 ng/g.
- PFOA and PFOS were infrequently detected in sediment samples from either water body and through the depth profile. Detections of PFOA were all estimated (i.e., "J" flag) and less than 1 ng/g. The maximum PFOS concentration is 1.6 ng/g, qualified as "JB", from SESW-01 (18–24 in. depth interval) collected from Little Mantua Creek.
- PFUnDA is present at less than 1 to 2 ng/g in all sediment samples at depth (18–24 in.), and in all surface sediment samples (<1 ft) collected closest to the confluence with the river. However, at locations furthest from the river in both Little Mantua Creek (SESW-03) and the Main Ditch (SESW-05 and SESW-06), PFUnDA is present in the surface sediment at concentrations ranging from 5 to 42 ng/g. PFNA also exhibits relatively higher concentrations (i.e., 5 ng/g) in surface sediment at SESW-06, but not at SESW-03 or SESW-05. These patterns are consistent with the tendency for higher carbon-chain PFASs to exhibit lower vertical mobility than lower carbon-chain PFASs. The locations of the peak concentrations likely correspond with areas of greater sediment deposition within the tidal creeks.
- Isomer chemistry composition was evaluated in a similar manner as the isomer evaluation of groundwater samples discussed previously (Section 5.2.1). Branched PFNA was detected at each sediment sampling location at one or more depth intervals, ranging from 3% to 21% of the mass of PFNA.

Overall, distribution of PFASs in the creek sediment is relatively homogeneous. Higher concentrations were observed in depositional areas of the two creeks near the Plant, furthest from the confluence with the river. The maximum PFAS concentrations are from samples collected at comparable distances from the river in both creeks – SESW-06 in the Main Ditch and SESW-01 in Little Mantua Creek. Near the river, throughout the 0–3 ft depth profile, results from samples collected near the river in 2016 are comparable to nearby locations that were investigated in 2014. The presence of branched PFNA at each location and across multiple depth intervals indicates that one or more additional sources of PFNA have contributed to the system over time.

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A correlation analysis was performed to examine the relationships between PFAS and sediment properties. Data were compiled for nine locations near the confluence of the river and creeks in 2014, and seven locations sampled in 2016. Among the 44 samples with results, 18 (40%) are surface sediment (top 6 in.), 11 (23%) represent depths between 0.5 and 1 ft, and 15 (34%) represent >1 to 3 ft. PFNA and PFUnDA were selected from the PFAS chemistry results because they are more frequently detected than the lower carbon-chain PFASs. PFNA exhibits a moderate positive correlation with PFUnDA (Spearman rho = 0.6) and TOC (rho = 0.5), but PFNA does not exhibit a consistent pattern with sediment depth or grain size distribution. Correlation matrix plots and additional details regarding the correlation analysis methods and findings are presented in Appendix H.

5.5 PORE WATER SAMPLE RESULTS

The results of the pore water sampling for PFASs are presented on Table 12, depicted in Figure 14, and summarized below. Results from sampling of the river sediment near the Plant in 2014 are included for comparison with the 2016 sampling. The results of the analysis for conventional parameters are summarized in Table 13.

- PFASs, including PFOA, PFOS, PFNA, and PFUnDA, were detected in pore water samples collected from each of six samples – four locations in Little Mantua Creek and two locations in the Main Ditch.
- PFAS concentrations in pore water are generally higher than co-located surface water concentrations.
- PFNA was detected at concentrations ranging from 86 ng/L at SESW-09 to 940 ng/L at SESW04. The highest concentrations of PFNA in pore water are found in the Main Ditch. No branched isomers of PFNA were detected in pore water samples.
- PFUnDA, was detected in surface water samples at concentrations ranging from 3.6 ng/L at SESW-08 to 110 ng/L at SESW-06. The highest concentrations of PFUnDA are found in the Main Ditch.
- PFOS, which was not detected or detected at levels just above the method detection limit (MDL) in sediment was detected at concentrations ranging from 11 ng/L at SESW-08 (qualified "JB" result due to blank contamination) to 75 ng/L at SESW-04. Similar to PFNA, the highest concentrations of PFOS in pore water were found in the Main Ditch.
- PFOA, which was not detected or detected at levels just above the MDL in sediment, was detected in pore water at all locations at concentrations ranging from 14 to 130 ng/L. The maximum PFOA concentration is for the sample collected from SESW-04. This concentration is 3 to 10 times higher than PFOA measured in pore water at other locations, and co-occurs with the maximum concentrations of PFNA (940 ng/L) and PFOS (75 ng/L), but not PFUnDA (11 ng/L, the lowest concentrations in Main Ditch).

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- Concentrations of PFASs at the two locations at the confluence with the river (SESW-08 for Little Mantua Creek, and SESW-09 for Main Ditch) are generally lower than concentrations at locations further downstream, and are very comparable to the results from three nearby locations in the river which was sampled in 2014 (see Figure 14).

Concentrations of conventional parameters (cations/anions) in pore water are comparable (within a factor of 2) to concentrations in surface water for chloride, calcium, magnesium, potassium, and sodium, and also low or nondetect for bromide and fluoride. Concentrations are more than an order of magnitude higher in pore water than surface water for iron and manganese, which may be indicative of turbidity in the samples.

A correlation analysis was performed to examine the relationships between PFASs in pore water and sediment, as well as conventional water quality parameters and sediment properties. Data were compiled for three locations near the confluence of the river and creeks in 2014, and six locations sampled in 2016. Correlation matrix plots and additional details regarding the correlation analysis methods and findings are presented in Appendix H. For comparison purposes, concentrations in sediment are based on the arithmetic mean across (co-located) depth intervals. The following findings are noted:

- PFNA in pore water is strongly correlated with PFOA (Spearman rho = 0.9), moderately correlated with PFOS (rho = 0.6), and moderately inversely correlated with PFBS (rho = -0.5).
- PFNA in pore water is strongly correlated with PFNA in sediment (Spearman rho = 0.8) and inversely correlated with percent clay (rho = -0.7).
- PFUnDA in pore water is strongly correlated with PFUnDA in sediment (Spearman rho = 0.8) and weakly correlated with sediment grain size distribution (rho ≤ 0.3).
- PFNA in pore water exhibits a moderate to strong correlation with several conventional parameters in the sediment, including chloride (rho = 0.8), sodium (rho = 0.7), potassium (rho = 0.6), and magnesium (rho = 0.5).

The relationship between PFNA and iron in pore water is illustrated below (see Graphic 8). For the three samples collected in 2014 from the river sediment, both iron and PFNA concentrations in pore water were relatively low. For the four samples collected in 2016, there appears to be an inverse relationship, suggesting that PFNA concentrations are not strongly influenced by turbidity of the sample.

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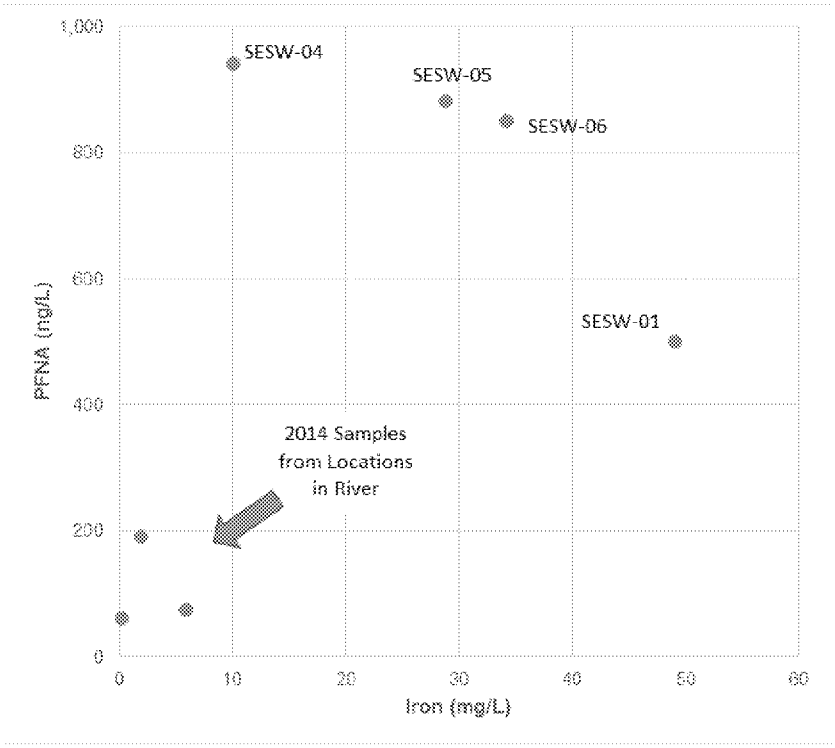

Graphic 8. PFNA and Iron Concentrations in Pore Water Samples Collected in 2014 from the Delaware River near the Plant, and in 2016 from Little Mantua Creek and the Main Ditch.

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6 SUMMARY AND CONCLUSIONS

The objectives of the investigation activities outlined in the Work Plan were to evaluate the presence of PFNA and other PFASs, in soil, groundwater, surface water, and sediment, and their potential transport pathways to groundwater. Those objectives were met and include the following findings:

- **Soil.** An area of elevated PFASs in soil has been identified at the Plant. This area corresponds to the highest observed PFAS concentrations, in particular PFNA, and vertical distribution of PFAS compounds and is located within and proximate to the production area (Polymer Building) and materials storage areas. PFAS levels, in particular PFNA, in soil outside of this area on the Plant site are considered minor and are not believed to represent a significant source of PFNA to groundwater. These lower levels of PFASs in soils outside the production area may be the result of air deposition from identified emission sources located near the Polymer Building. This is consistent with the significant decrease in PFAS in soil on the Plant site with distance downwind from the identified emissions sources.

  Soil desorption equilibrium testing of Plant site soils was conducted and yielded site-specific partition coefficients for PFNA. Applying this information and NJDEP's spreadsheet tool for calculating preliminary site-specific IGW SRS, yielded a value of 20 ng/g or 0.020 mg/kg for PFNA in soil.

  Regarding offsite soils, including both the TWP soil samples collected at depth in 2014 and the surface samples collected in 2016, PFNA was not detected (<1 ng/g) at most locations. The maximum PFNA concentration in offsite soil (2.6 ng/g at boring MW-103S) is lower than the IGW SRS by approximately an order of magnitude. Based on the concentration gradient (e.g., the concentration of PFNA at location MW-101, located closest to the site, is lower than that observed at all other locations), there is no discernible direct pathway from the site, which is consistent with results of the air dispersion modeling.

- **Groundwater:** Groundwater flow in the Upper PRM, the primary aquifer evaluated as part of the implementation of the Work Plan, is to the south-southeast. The groundwater flow direction measured during this recent investigation is consistent with water levels previously observed in onsite and offsite Solvay monitoring wells (ERM 2014). For groundwater to flow from the Plant to wells located near Woodbury Creek, it would need to flow cross gradient from the flow direction observed at the Plant, and through the monitoring well transect including MW-101S/D, MW102S/D, and MW-103S/D. The data collected during this study do not support such a groundwater flow path. Rather, the water level gauging data coupled with the spatial distribution of PFAS results (including isomer chemistry) indicate that there is no hydrologic connection between groundwater at the Plant and groundwater near Woodbury Creek.

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PFASs in groundwater have been characterized along the flow path including delineation of the downgradient extent of PFAS as defined by monitoring wells MW-108S/MW-108D and delineation along the southwest edge of the plume as defined by monitoring wells MW105S/MW-105D and MW-106S/MW-106D.

Furthermore, an evaluation of branched and linear isomer composition of the groundwater samples shows that branched PFNA and PFOA is present from source(s) not related to Solvay or historic operations at the Plant location that preceded Solvay. To Solvay's knowledge, historic Plant operations used only linear PFNA and this is consistent with the exclusively linear PFNA found in Plant groundwater. This finding contrasts with isomer chemistry evidence of co-mingling of plumes from sources other than the Plant that are occurring in the down and cross gradient area investigated.

- **Sediment/Surface Water/Pore Water:** Some fraction of the PFASs in sediment proximate to the Plant may reflect historic aerial deposition to onsite soil, subsequent leaching to shallow groundwater, and transport from groundwater to adjacent surface water. Preliminary evidence that shallow groundwater near the site discharges to both the Main Ditch and Little Mantua Creek includes the range of PFAS concentrations measured in pore water, sediment, and surface water. PFNA concentrations are highest at locations furthest inland (away from the river) in substrate comprised of larger grain sizes. Branched isomers of PFNA detected in surface water and sediment collected from both the Main Ditch and Little Mantua Creek originated from source(s) not related to Solvay or historic operations at the Plant that preceded Solvay.

The findings from this investigation address the key objectives of the Work Plan and provide an improved understanding of potential sources and transport pathways that contribute to the distribution of PFNA and other PFASs in the environment. Solvay requests a meeting with the NJDEP to discuss the findings and next steps. Thereafter, Solvay, in conjunction with the LSRP, will develop and submit to NJDEP a Work Plan that outlines additional investigation goals and activities.

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